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The Mormon Cricket

with

Suggestions For Its Control

By Claude Wakeland and W. E. Shull

COOPERATIVE EXTENSION SERVICE IN AGRICULTURE AND HOME ECONOMICS OF THE STATE OF IDAHO UNIVERSITY OF IDAHO EXTENSION DIVISION AND UNITED STATES DEPARTMENT OF AGRICULTURE COOPERATING

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Summary

Mormon crickets are known to have been present in Idaho several different times previous to 1932, which year was their first appearance on agricultural land in the present outbreak. The severity of the outbreak has increased steadily from year to year since 1932. They now infest nearly 2,000,000 acres in 24 counties.

Mormon crickets have a one-year life cycle. Eggs begin to hatch as early as the middle of March. Crickets reach maturity in from 75 to 100 days and ten days or two weeks later, eggs for the new generation are laid. Eggs incubate throughout the summer and the early fall, thus fully-developed nymphs pass the winter inside the eggshell.

Mormon crickets have certain definite behaviors, many of which seem to be in response to changes of temperature, which control their activity at any time during the day. The practice of the control methods must be based on an understanding of these behaviors.

Mormon crickets seem to prefer *Balsamorrhiza*, danelion, and young mustard plants, but will atttack nearly any green plants in their range. They may cause damage to range, garden, cereal, potato, and many other crops.

The Mormon cricket is found extensively only in eight western states. The breeding areas in Idaho are in the higher hills in eastern Idaho on both sides of the Snake River and its tributaries, the higher hills drained by the Bear River in southeastern Idaho, the foothill area along the north side of the Snake River and its tributaries in southwestern Idaho, and in the mountains in northern Idaho drained by the Salmon and Snake Rivers.

Weather seems to have little influence in the control of Mormon crickets. Hawks and blackbirds are the most important of the bird feeders. Hairworms, which attack the crickets, are found in abundance in the small streams tributary to the Boise River.

Eggs in agricultural land may be plowed under deeply late in the fall or early in the spring, preventing young crickets from escaping from the ground.

Rivers, creeks, irrigating canals, trenches and fences form useful barriers to the migration of the crickets only under certain conditions. Trenches must be properly constructed to prove effective. Fencing is expensive and very limited in its usefulness.

The most effective control for the Mormon cricket is the application of a poisoned dust prepared from 1 pound of sodium arsenite mixed with 4 pounds of hydrated lime, or, 1 pound of calcium arsenite mixed with 3 pounds of hydrated lime. This material is applied directly to the bodies of the crickets with a hand-cranked dust gun. Control by dusting is most effective soon after crickets hatch. The poison should be applied only when the crickets are bunched. Five pounds of poisoned dust should be sufficient to control the crickets on one infested acre. Poisoned baits have not proven entirely satisfactory.

The poisons are not dangerous to animals if correctly used. Operators of dust guns should take proper precautions to protect themselves against injury by poisoned dust.

Cooperation of all parties involved in cricket-infested areas is a necessity to adequate control.

The Mormon Cricket

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Suggestions For Its Control

By Claude Wakeland and W. E. Shull*

History Of The Present Outbreak

THE present outbreak of the Mormon cricket in Idaho has continued four years, during which period the insect has increased alarmingly in numbers and distribution. No warning of this outbreak was observed until hordes of "crickets" had reached the irrigation canal at Fort Hall in May, 1932. They floated down the canal for miles, occasioning widespread alarm as they reached the irrigated land alive. "Crickets", of course, had been present in very small numbers in remote areas of the State since the last general outbreak some 18 or 20 years ago. Information gathered from stockmen and Indians indicated that large bands of "crickets" were observed defoliating range plants in the Fort Hall area at least two years before they reached the canal. This condition is not unusual in the higher areas remote from agricultural land and, therefore, was not reported, nor considered alarming.

No funds were available when the need for repelling invading bands in the Fort Hall area first arose, but in the frenzy of excitement prevailing, volunteer laborers were abundant and such workers dug approximately 50 miles of trenches in 1932. At times, as many as 300 workers per day participated. Most of the volunteers at first were farmers who left their own farm work to aid in repelling the "crickets", but as their interest lessened and their farm work demanded their time, relief labor filled their places. Relief labor was supplied through social welfare agencies and such organizations as chambers of commerce. Little was accomplished with this latter class of labor for it did not work well under supervision and apparently was not interested in "cricket" control.

The "crickets" in the Fort Hall area were all within the confines of the Indian reservation. Mr. F. A. Gross, superintendent of the Fort Hall Indian Agency, succeeded in obtaining some funds through the Department of the Interior for use in the emergency, most of which was spent for food and transportation of volunteer workers, tools and materials for poisoned dust. The poison dust materials were received too late to be of much service the first year. The Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, furnished 25 hand dust guns. Bannock county appropriated $500 for tools and transportation. Bannock and Bingham counties donated the use of their road crews and grading equipment as well as the services of many of their county officials. The State, through the office of the governor, provided $500 which was spent for barrier materials. Nearly all the field and shop employees of the Fort Hall Indian Reservation aided in the attempt to prevent "crickets"

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from reaching agricultural land, and the entire Indian Service sacrificed regular work to meet the emergency.

Small outbreaks occurred in 1932 in several other localities but did not seriously threaten agricultural lands. Outbreaks were more general and larger in 1933. During that year sodium arsenite dust was used extensively for control at Fort Hall and in Fremont County and, by the same means, control was undertaken in a small way in Elmore County. Control on the Indian Reservation was done by workers in established E. C. W. camps; in Fremont county it was done by volunteer and relief crews under the direction of the county agricultural agent with funds provided by county appropriation. Volunteers or individual farmers did the work in Elmore County, under the direction of the county agricultural agent, with funds provided by the county. Many new outbreaks attracted attention in 1934, but control work was not undertaken in any new areas. The same general plan was followed in each of these three counties, excepting that the work was much more extensive than in 1933 and more of the cost was met by the Idaho Emergency Relief Administration, which paid for most of the labor used.

The governor's drought relief committee allotted $6,100 in 1934 for Mormon "cricket" control. This became available too late to be of service in 1934 but supplies were purchased and delivered to the counties where they would be needed the following year.

"Cricket" control work was conducted in 12 counties during the 1935 season at a total cost of $26,374.21 expended as follows: dust guns, $1,047.50; sodium arsenite, $1,645.25; hydrated lime, $664.35; barriers, $2,854.30; labor and transportation, $20,163.81. Individual counties expended $8,115.91, and the Idaho Emergency Relief Administration expended $18,258.30. It was calculated that 742 men working 29,991 hours dusted 9,729 acres in crop.

History of Earlier Outbreaks.

According to historical records (Bancroft, 1889) Mormon crickets caused the first crop losses in the United States when they destroyed the crops of the Mormon pioneers in the Great Salt Lake Basin in 1848. "The name 'Mormon' was probably adopted because of the incident just mentioned, and 'cricket' because the insect somewhat resembles the common black field cricket especially in its chirping noises." (Cowan, 1929).

There is nothing unusual in the present outbreak unless it be the suddenness of the invasion of agricultural lands. Records of outbreaks in the past are meager but observations made by old residents of the State and such printed records as exist appear to indicate that Mormon crickets have reached outbreak proportions about every 30 years with lesser outbreaks at about 15-year intervals. Thus it appears that there was a minor outbreak about 1917, a major outbreak about 1903, and either a major or a minor outbreak about 1888. Cyrus Thomas in 1871, C. V. Riley in 1880, and Lawrence Bruner in 1883, describe the extensive bands of Mormon crickets encountered in their travels in Idaho in much the same area infested today.

Methods of combating the Mormon cricket remained nearly unchanged

from the time settlers first were called upon to protect their scanty crops from the ravages of these insects until 1927, when sodium arsenite (Cowan, 1929) first was used as a means of chemical control. The following account published in 1883 indicates that some of the control methods used today were employed at a very early period in Idaho civilization. According to Lawrence Bruner (1883), "if a ditch two feet wide and two and a half feet deep be dug across their line of march they will fall into it and cannot get out. By putting in larger pits at intervals they are doubly 'corralled' and soon begin destroying one another, as they are great cannibals." A pioneer in the Lewiston district reports that an extensive outbreak occurred there in 1883 and crickets damaged garden and field crops. Trenches were dug as a means of preventing them from migrating from range to crop lands.

Fences were used at least as early as 1903 when, according to reports of early settlers, ten miles of them were erected in Fremont County to prevent crickets from invading agricultural areas. These were made of lumber, faced with metal and erected vertically with the metal toward the invading bands. Evidence of the old fences still remains. Reports from men who helped in the work are that pits were dug at intervals along the barrier face and that countless numbers of the insects thus were trapped and killed. An ingenius device used in Fremont County, which is said to have been effective in preventing crickets from floating alive down irrigation canals, consisted of two rollers placed wringer-like across the canal and operated by a water wheel. The rollers were set so that the crickets floating on the surface of the water passed between, crushing them.

Other early settlers in Idaho remember when Mormon crickets destroyed their gardens, grain and alfalfa fields as early as 1888, and describe the enormous hordes of the insects as filling small canyons and damming up small creeks. Their recollection is that bands of the crickets then were as large or larger than those in the present outbreak but that the damage they caused was much less severe, which they explain by the fact that 45 years ago the insects had an abundance of native vegetation on which to feed while now they are driven more to cultivated crops from the lack of native vegetation which largely has been destroyed by over-grazing of domestic animals.

Species Involved

The so-called "Mormon cricket" is not a true cricket as the common name implies, but is in reality a grasshopper. Grasshoppers are divided into two groups; the short-horned grasshoppers or *Locustidae;* and the long-horned grasshoppers or *Tettigoniidae.* The two groups are separated partially by the fact that one has long antennae, or feelers, and the other has short ones. The Mormon cricket belongs to to the group having long antennae. Its scientific name is *Anabrus simplex* Hald.

There are several grasshoppers in the State which appear to be very much like the Mormon cricket but which are a different species entirely, and probably are being confused with true Mormon crickets. Many of those insects which have been called the Mormon cricket may be in reality some other species.

Seasonal History

The Mormon cricket completes but one generation annually. The winter is passed in the egg stage. Eggs begin to hatch after the occurence of a few consecutive warm days in the spring, usually about March 25 in the lower, warmer areas as in Elmore County and not until about June 1 in the higher, colder areas as in upper Fremont, upper Bonneville or Teton Counties. The young crickets begin to feed soon after hatching, if the weather is warm, and grow rapidly, reaching maturity in from 75 to 100 days. Ten days or two weeks after reaching maturity the crickets have mated and begun to lay eggs. Egg-laying begins in Idaho in late June or in July, according to elevation and temperature, and continues in the higher elevations until cold weather. Many of the adults begin to die soon after mating, the death rate increases as the autumn advances but a few stragglers remain alive, in the higher elevations until well after the first freezes.

—Photo by Bur. of Ent. and Plant Quar., U. S. D. A.
Fig. 1.—Eggs of the Mormon cricket, numbering 870, taken from 1 square foot of soil.

Eggs

The eggs of the Mormon cricket resemble grains of rye in shape and appearance. (*Fig.* 1). They are a little more than ¼ inch long and from one fourth to one third as wide as they are long. They are dark brown when first laid but soon change to bluish gray. Eggs incubate during the late summer and fall. Thus the fully formed young cricket nymphs remain in the egg during the winter and are ready to emerge with the first warm days of spring. The eggs are deposited one at a time but often several eggs are laid in groups by the same female. Most of the eggs are deposited just below the soil surface at a depth of about ¼ inch but some of them are buried deeper.

According to Cowan and McCampbell (1929), "When a female cricket is ready to deposit an egg, she walks around with the tip of her abdomen raised and the ovipositor pointed downward in an almost vertical position. In this way the soil is tested in several places until one suitable for oviposition is found. The ovipositor is then worked into the soil by a shuttle-like movement of the right and left valves by means of a pair of long inner valves. After the egg is placed in the ground, the ovipositor is withdrawn and the opening of the hole closed by means of a few quick, backward movements of the ovipositor.

"Practically all types of soil are used by ovipositing females, with a light, sandy soil perhaps a trifle favored. A sunny exposure is usually chosen where the ground is more or less bare of vegetation."

The number of eggs a female will lay is not definitely known. Fifteen females held in separate cages at the Billings, Montana, laboratory of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, deposited an average of 85 eggs each, with a maximum of 160. Probably 150 eggs per female is a fair average under field conditions. (Cowan, 1929).

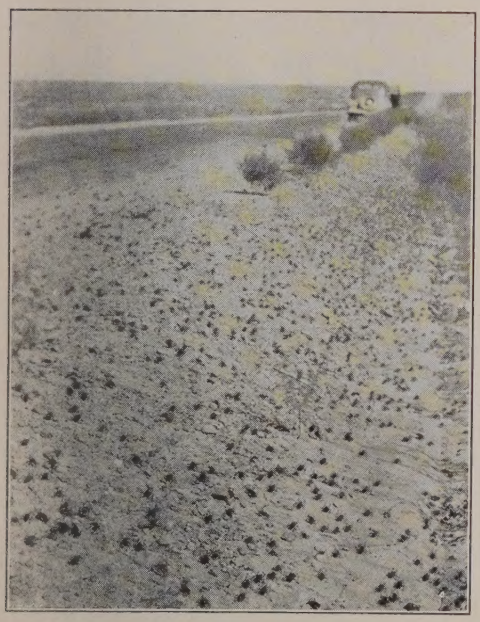


Fig. 2.—Mormon crickets on the march. This band migrating out of the sagebrush, upon reaching the highway, changed direction and followed along the roadside.

Nymphs.

When young crickets emerge from the ground they are about one-fourth inch long, light tan in color at first but soon changing to dark brown or nearly black. The Mormon cricket passes through seven growth periods, known as instars, each of which lasts for ten days or two weeks, before it reaches maturity. The body covering will not stretch to accommodate growth, so must be shed or molted. The process of molting requires only about 10 or 15 minutes. The cricket fastens itself by its hind legs to a stem of grass, sage brush, etc., where it remains suspended, head downward. Cowan and McCampbell (1929) describe growth periods and the process of molting as follows: "Soon a swelling is noticed on the back just behind the head, caused by the muscular contraction of the body. This swelling serves to split the old covering down the center of the back from the center of the top of the head to half way back on the abdomen. Through this vent, the body, by a series of twisting movements from side to side, is pushed out from the old skin, commencing with the head, antennae and mouth-parts and continuing with the two front pairs of legs. The hind legs are then withdrawn with the aid of the two front pairs and further twisting movements of the body. The tip of the abdomen is finally freed and the young cricket drops to the ground with a new and larger covering which is pinkish-brown in color.

"It will usually remain quietly where it falls until the new coat has

hardened. In the first four stages, the color is usually black with white markings on the top of the body and on the sides of the prothoracic shield. In the more advanced stages the color may vary to green and black, red or brown.

"In the female of this insect, the growth of the ovipositor is the best index to the various stages of growth or instars. During the first two instars the ovipositor is not visible to the naked eye. In the third, it is

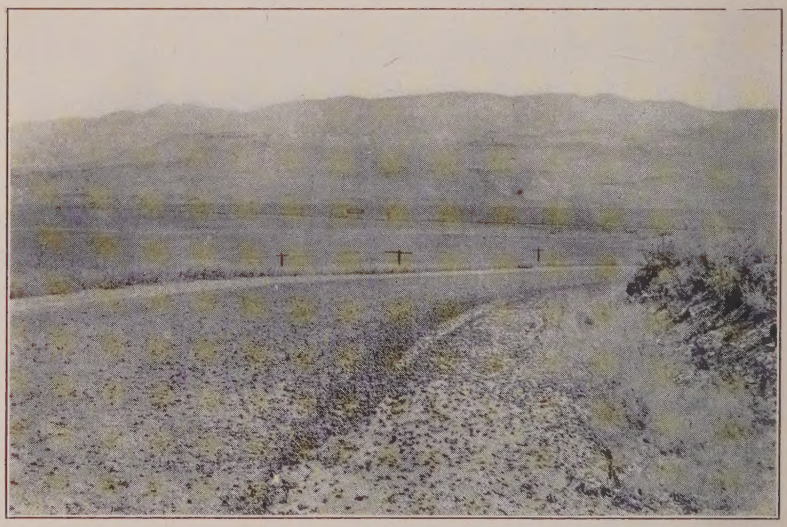


Fig. 3.—Migrating crickets on the highway. Crickets crushed by automobiles are pounced upon greedily by their cannibalistic companions.

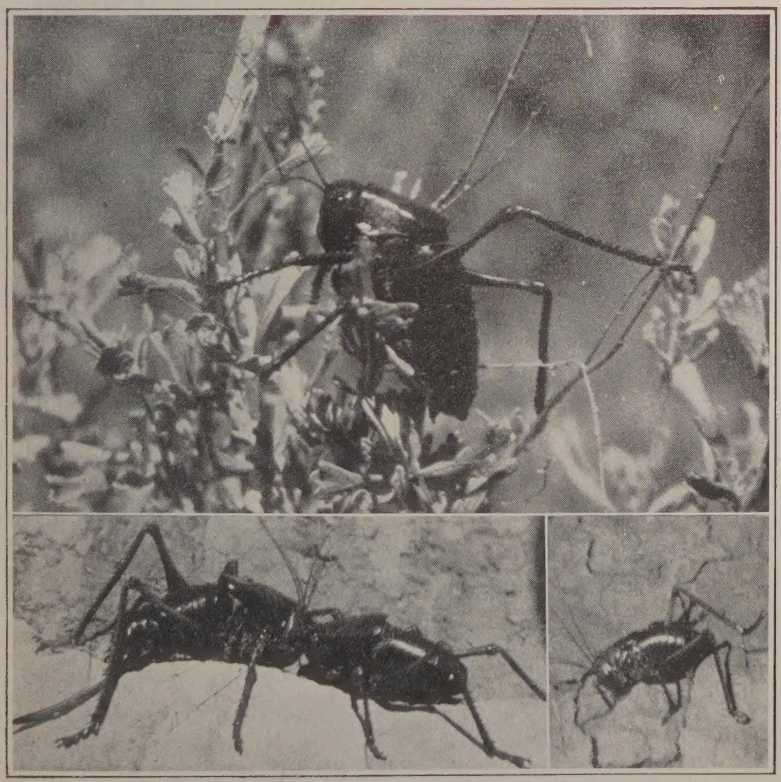
plainly visible, but does not extend past the tip of the abdomen. From this time on it doubles in length after each molt, with the exception of the sixth or next to the last. That is, the seventh instar females have an ovipositor practically as long as the adult, the difference being that the ovipositor of the adult is much heavier and stouter at the base."

Adults

The adult crickets are uniformly dark brown to black as a general thing but a few exceptions have been noted in certain localities in Idaho where they remain dark green or pale brown for at least a month after reaching maturity. The body of the cricket averages about 1¼ inches in length and 5/16 inch in width. The female has a sword-like ovipositor protruding from her posterior end about one-half to two-thirds the length of her body. Crickets cannot fly, but small vestiges of wings are present. The two fore wings of the male are equipped with sounding organs which, when drawn across one another produce a chirping or "squeaking" noise. The males chirp when disturbed and more or less continuously during the mating period.

Behavior

The Mormon cricket has certain definite behaviors, many of which appear to be in response to changes of temperature. When bands of crickets are not dispersed by control activities during the egg-laying period they tend to deposit their eggs in rather definite, restricted areas so that the newly hatched nymphs are found in groups with large, unpopulated areas between. Soon after emerging from the ground, the nymphs tend to collect into still denser groups. A band of crickets which at that stage may cover an area of only a few square rods, will after migration and growth take place, cover an area of several acres. If the weather is cold and wet, newly emerged nymphs huddle together under protecting brush, rocks, etc., remaining comparatively inactive until the temperature rises, but otherwise are little affected by the cold, snowy or rainy weather of early spring. As the temperature rises with the advance of spring they begin to feed and scatter, but throughout their lives they seek protec-



—From An. Rpt. Colo. State Ent., Colo. State Ent. Cir. 36, 1922.

Fig. 4.—Upper: Male of Mormon cricket roosting on sagebrush. Lower left: Male and female courting. Lower right: Female laying her eggs in the ground.

tion as soon as the temperature drops in the evening or during cool, stormy days.

The clustering habit of crickets has an important bearing on their control by the use of arsenite dusts for they are to be found concentrated in dense groups on rocks, brush, posts, etc., in the late evening and in the early morning during periods of moderate day-time temperature and in the middle of the day during periods of intensely hot weather.

Fig. 5.—Dry-farmed wheat completely ruined by the feeding of Mormon crickets, a few of which still are remaining in the wheat.

They become restless and begin to migrate (*Figs. 2 and* 3) after they have reached the third or fourth instar and then are on the move constantly except during the time they are "roosting", feeding, or egg-laying. Individual bands move as an army in a more or less fixed direction, but the general direction of march may be changed from day to day. In any single area bands may be migrating in almost every direction at the same time, and individual bands tend to lose their identity after mingling with other bands which may be traveling in different directions. A single migrating band tends to follow its general direction of march regardless of obstacles encountered. Thus bands occasionally have been observed to travel over fences, walls and houses and frequently to plunge into canals, creeks, and rivers. Most of them drown in large swift-flowing rivers but in smaller or slowly moving streams many swim and float until carried to the opposite bank onto which they crawl by grasping overhanging branches or the roots of plants.

The younger crickets confine their feeding to low-growing shrubs and tender grasses and weeds on the surface of the ground. As they grow in size and increase in strength they attack taller grasses and bushes, and when they are in the last instars or are mature they defoliate portions of shrubs, such as chokecherry and syringa, 10 or 15 feet in height. Much of their feeding appears to be in response to their need of moisture for

after weeds and range grasses mature or dry up from lack of moisture, the crickets attack succulent vegetation which earlier in the season appears unattractive to them. For example, they do not appear to relish "skunk cabbage" in the early season, but later in the season they have been observed to attack the leaves of this plant, devour them completely, and then to attack the stems, eating to the ground stalks which are 5 feet tall and 1½ inches in diameter at the base.

Fig. 6.—Irrigated wheat damaged by Mormon crickets. The insects migrated into the field from the range and cause the injury all along one side of the wheat field.

The Mormon cricket is cannibalistic; uninjured crickets attack fiercely any members of the band which may have been injured, and soon devour everything excepting the legs, head and tougher body covering of the injured individuals. This habit appears to have little effect on the size of a band or amount of damage it is capable of doing. The habit of cannibalism renders it difficult to judge the results of control work by poisoning, for nearly all of the bodies of poisoned crickets soon are devoured and it is difficult to detect the remaining parts.

Food Plants

Mormon crickets show definite preference for certain food plants on their range but in the scarcity or absence of these they appear to devour any kind of green vegetation. They almost completely defoliate *Balsamorrhiza* (locally called sunflowers) before attacking other plants to any extent. They also prefer dandeloin and young mustard plants, often devouring these completely before attacking cultivated crops in which they are growing. They do not feed extensively on range grasses, for most of these are mature and tough before crickets are large enough to

attack them; but they do materially reduce the reseeding possibilities of range grasses, for they cluster on the heads of mature grasses, devouring the seeds. Late in the season they attack the bases of perennial range plants. On occasion they defoliate and devour the bark of many shrubs and bushes and seem to be particularly fond of the blossoms. Injured shrubs observed have been chokecherry, service berry, wild currant, syringa and even sage brush (*Fig.* 4). A complete list of the plants upon which they would feed probably includes nearly every species in their habitat.

Damage by Mormon Crickets

Damage to Range Plants.

Probably the greatest source of damage from Mormon crickets in Idaho is their destruction of range plants. This goes on year after year. The actual amount of loss sustained is difficult to measure or even estimate, but since the insects are such voracious feeders it is reasonable to grant that where nearly 2,000,000 acres in the State are infested by them and where millions of them occur per acre, as they do, they are displacing many head of cattle, sheep, horses, and game animals on the Idaho range, as well as increasing the harmful effects of over-grazing. Stock will not graze over areas heavily populated with crickets.

Fig. 7.—Wheat injured by Mormon crickets. Note eaten leaves, injured head, and broken stems.

Damage to Gardens.

The damage from Mormon crickets which is the most evident and impressive is that caused to garden crops. Where the insects were not controlled, most of the gardens in the infested areas were destroyed completely in 1935. The foliage of practically all varieties of garden crops is eaten to the ground and root crops or heavy-stemmed crops are eaten well into the ground. Small-fruit bushes and fruit trees are defoliated and killed by girdling when the crickets devour the bark. Even in gardens where control of the crickets by dusting is obtained, the leafy vegetables are unfit for human food for they are contaminated by the liquid feces of crickets which have been sickened by sodium arsenite.

Damage to Farm Crops.

Experience in Idaho indicates that crickets prefer native vegetation to cultivated field or forage crops, a fact which explains why they have not destroyed farm crops more extensively. They are a dry-land insect and therefore attack irrigated crops only when bands occasionally invade the irrigated areas. Wheat and barley are attacked greedily (*Figs. 5 and 6*). The young plants are eaten to the ground. If plants are attacked in later stages of growth the crickets begin feeding on leaves, rapidly eating these back to the sheath and so weakening the stem that the head hangs downward (*Fig. 7*). After cereal crops are mature, or nearly so, the insects cluster on the heads, devouring the grains. Corn is relished by the crickets and the plants are devoured in their entirety. Damage to alfalfa has not been extensive in the infested area as a whole but in certain dry-farming localities it has been extreme, especially to seed crops. At first the insects attack single plants, defoliating them completely while adjacent plants remain almost untouched. Later they are likely to congregate on the terminals and cause general injury throughout the field. Terminal injury tends to be covered up by new growth from lateral buds and the field appears to have recovered, but close examination is likely to reveal that crickets have defoliated the lower portions of many of the plants, which are protected by the terminal leaves (*Fig. 8*). Migrating bands of crickets frequently come to rest in an alfalfa field, remaining there for days and even weeks at a time. In such cases they cause heavy injury, reducing the hay crop materially in quantity and even more so in quality, for that which is harvested consists mainly of stems.

Fig. 8.—Alfalfa plant injured by Mormon crickets. Note the lower part of the plant has been completely defoliated.

Psychological Influence.

Damage to crops doubtless would have been far greater in Idaho during the last four years had not a determined fight been waged against crickets when they threatened invasion of agricultural lands. In several districts the crickets now have made their way into agricultural lands where they are breeding and laying eggs, and it seems probable that if the populations do not die out naturally far greater damage will result than has been experienced to date in the present outbreak. Indeed, there are records of cases in other states, under similar conditions, where Mormon crickets

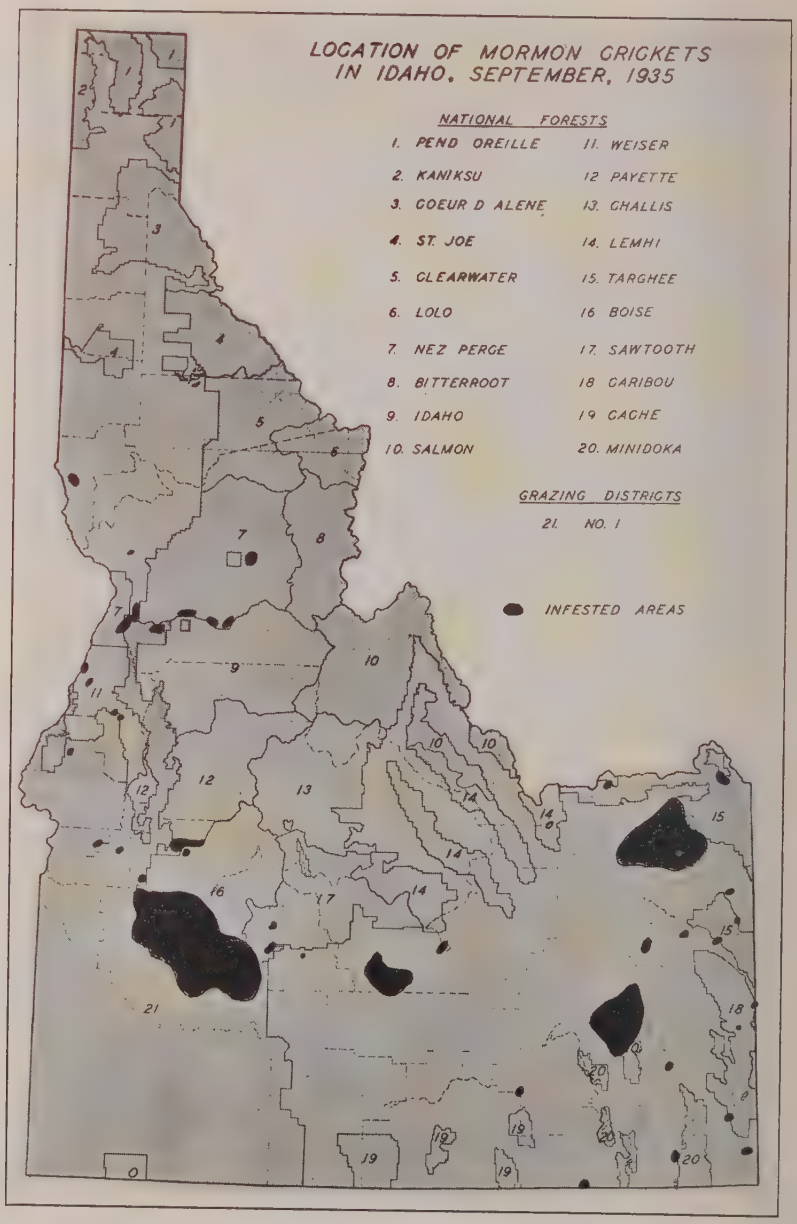


Fig. 9.—Showing the approximate area in Idaho infested with Mormon crickets in 1935. Approximate acreages infested are divided as follows: Public, state, or private lands, 1,127,000 acres; national forests, 475,000 acres; Indian Reservations, 219,000 acres; Grazing District No. 1, 529,380 acres.

have devastated large areas of choice agricultural lands. The fear of damage to come is demoralizing to a community which must face it year after year. When farmers have fought crickets for 65 consecutive days, as they did in some instances in 1935, they have little time left for regular farm work and are so sapped of energy and enthusiasm that the outcome seems hopeless. The psychological effect of Mormon crickets is even more important than the actual damage they have done for it influences adversely the farming operations in the infested areas.

Distribution

In the United States.

The Mormon cricket is of economic importance in the United States only in the states of Colorado, Idaho, Oregon, Montana, Nevada, Washington, Wyoming and Utah, although it is thought to occur as far north as southern Canada, east as far as Minnesota, and south as far as Arizona. Its native habitat is in the broken, mountainous regions more or less covered with sage brush, native shrubs and native grasses. In the higher hills of this region it can be found year after year, but only during "outbreak periods" does it become abundant enough to leave its natural habitat and migrate to cultivated lands.

Fig. 10.—Hairworms removed from the water in a small stream in Boise County after they had left the bodies of Mormon crickets. Note the gnarled masses in the hands of the observer and against the rock in the foreground.

In Idaho.

The natural breeding areas of the insect in Idaho appear to be the higher hills in eastern Idaho on both sides of the Snake River and its tributaries, the higher hills in the area drained by the Bear River in south-

eastern Idaho, the foothill area along the north side of the Snake River and its tributaries in central and southwestern Idaho, and the mountains of central and northern Idaho which are drained by the Salmon and the Snake Rivers. It has been found in nearly all of the counties of the State but appears to have reached outbreak conditions only in the areas mentioned. In the present outbreak, the insect has become so abundant that it has migrated downward from its natural habitat and has reached much of the dry-farming area and some of the irrigated land lying adjacent to its natural breeding areas. Forty-four infested areas, varying from small to exceedingly large, are now known to occur in 24 counties. These are indicated on the accompanying map. (*Fig.* 9).

Fig. 11.—Barrier trap in position in an irrigation canal. Note the barrier floats, the metal face, the Y-shaped trough with the lower end partly submerged, and the pit.

Control of the Mormon Cricket

Nothing is known or definitely recorded of the factors which influence the rapid increase or the sudden decrease of Mormon cricket populations. Natural factors which might be expected to exert an influence are weather, disease, birds, rodents, parasitic or predacious insects or other parasites. During the present outbreak Idaho has experienced one of the mildest and one of the most severe winters on record but neither has been observed to affect the continually increasing population. No disease of Mormon crickets has been observed or is known to occur and no insects worthy of note have been observed to attack them in this state. In certain areas eggs have been uncovered and eaten by rodents and possibly by birds, but egg destruction had little effect on the size of the next year's population.

Control by Birds, Rodents, Insects and Hairworms.

Birds have been the most important natural enemies of the Mormon cricket in Idaho and even the effect of these has not been measurable. Hawks feed greedily on the crickets but their numbers are too few to result in any great reduction of the bands. They assemble in droves and may follow a migrating band of crickets for miles. At times they feed and at other times they may be observed on posts or brush nearby where, perched as sentinals, they mark the presence of the band. When crickets migrate near to irrigated land they are attacked by large bands of blackbirds, many of which have been observed to feed on them day after day

without noticeably diminishing their numbers. Crows seldom have been observed to feed on Mormon crickets.

Hairworms were recorded in 1880 as killing Mormon crickets in eastern Idaho, (Riley, 1880). They were found to be abundant in 1935 in the small streams tributary to the Boise River (*Fig.* 10) and some of them were found in the bodies of the crickets. Residents of that area reported that fully one-half of the crickets they killed during a short period of time contained these hairworms*, which grow to be very large within the bodies of the crickets, occasionally reaching a length of 48 inches. They kill many of the crickets affected and render the others infertile. Little is known of their biology. They may effect a marked reduction in cricket populations in restricted areas but since they are not known to occur in the arid areas where most of the crickets are, their influence on the cricket population of the state as a whole cannot be expected to be very great.

Fig. 12.—Canal trap: crickets gathering in mouth of the trough and crawling up the inclined chute to drop into the pit-trap.

Control by Cultivation.

When eggs of the Mormon cricket are known to occur in agricultural lands, or open land adjacent, they may be plowed under deeply in the autumn or in the spring before they hatch. Plowing should be followed by discing or otherwise working the surface to pack it down and fill crevices. Young crickets hatching from eggs in soil handled in this manner are unable to reach the surface.

Control by Barriers.

Barriers which more or less effectively prevent crickets from migrating to agricultural lands are rivers, creeks, irrigation canals, trenches and fences. The most effective natural barriers are rapidly flowing rivers with steep banks. Most of the crickets jumping into such rivers are drowned before reaching the other side or before being carried by irrigation canals to farming land below. Rivers, however, are of little importance since the habitat of the crickets is such that migrating bands rarely reach sizable streams. Creeks usually do not serve to stop migrating bands for they soon make their way across them with the assistance of debris, grass, and over-hanging brush along the creek banks.

Canal barriers. Irrigation canals are the most effective barrier which

* *Gordius villoti* Rosa. Determined by Dr. G. Steiner, Bureau of Nematology, U. S. Dept. of Agriculture.

can be used to aid man in preventing crickets from reaching irrigated land. Crickets migrating from range to irrigated land may have to cross a canal where they may be trapped economically. The trap consists of a barrier across the canal, a chute in which the crickets can crawl out of the stream, and a pit to prevent them from escaping (*Figs.* 11 *and* 12). The barrier, constructed of timbers buoyant enough to permit workers to cross on them, is anchored to each bank and diagonally across the canal. The up-stream face of the barrier is faced with smooth sheet metal to prevent the insects from crawling over it (*Fig.* 11). Crickets floating down the stream are carried against the barrier and toward its down-stream end to the bank of the canal, where a Y-shaped trough converges to lead into a flume arising at the water's edge and sloping upward over the top of the bank (*Fig.* 12). The upper end of the flume projects out over a large, smooth-sided pit dug into the ground (*Fig.* 11). Crickets reaching the Y-shaped trough gain a footing on the rough bottom, crawl up the incline and drop into the pit where they soon succumb to over-crowding and suffocation. If swirls form in the water, sucking the insects beneath the barrier, the swirls may be broken up by suspending fine chicken wire or coarse sand-screen beneath the barrier. Crickets are aided in crawling out of the water and up the incline by pieces of brush or wire screening in the Y-shaped entrance and on the bottom of the chute. With a barrier of this type operated in the Fort Hall canal, a pit about 8 feet square was filled approximately 6 feet deep with crickets so the trough had to be extended to lead into another pit dug farther out on the bank. Where the current is fairly swift and the canal banks are free from brush or over-hanging grass, canal barriers almost entirely prevent crickets from reaching irrigated land, but where these conditions cannot be obtained the canal barrier is relatively ineffectual.

—Photo by H. A. Ireland

Fig. 13.—Mormon crickets trapped in a hand-dug trench.

Trenches. The oldest method of stopping crickets from migrating is the use of trenches dug in the ground. From the standpoint of labor requirement these are very expensive to build and maintain but from the standpoint of cash outlay they are the most economical type of barrier. In moderately sandy soil, trenches may stop a migrating band almost completely and when pits are dug at intervals in the bottoms of the trenches the crickets are trapped and countless millions of them perish (*Fig.* 13).

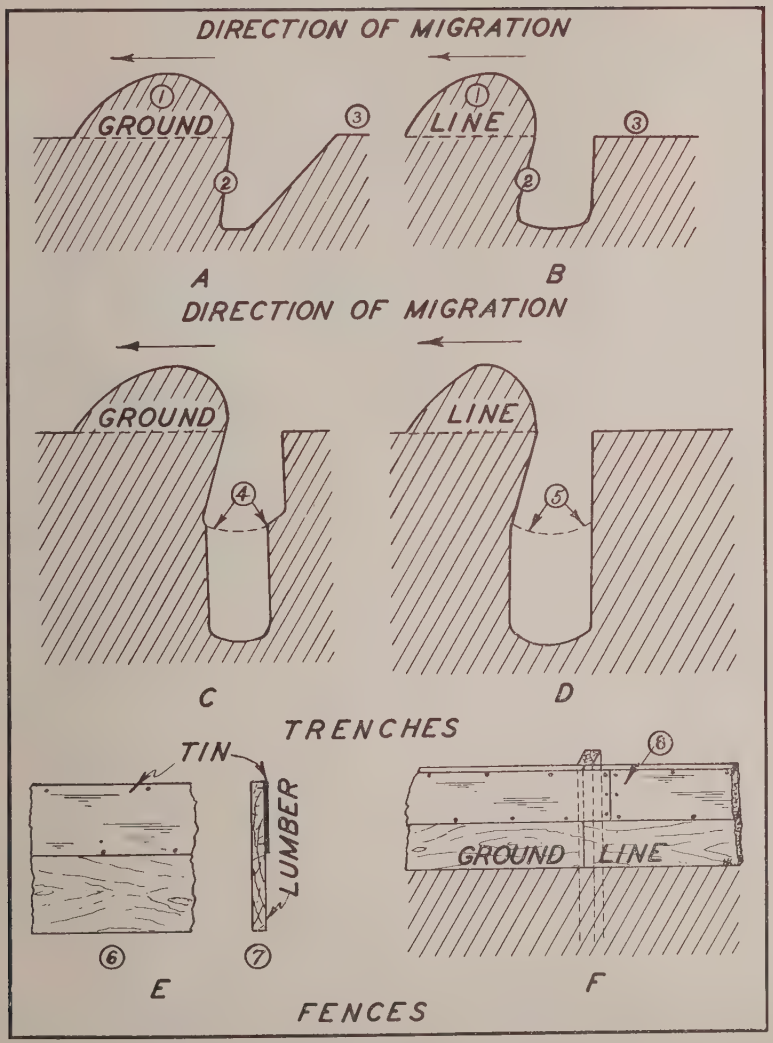


Fig. 14.—Mormon cricket trenches and fences:

A. & B.—*A*, trenches constructed with a road grader. *B*, constructed by hand. *A1* and *B1*, illustrating proper piling of soil removed from the trench. *A2* perpendicular, smooth outer wall and *B2*, undercut, smooth outer wall, necessary to prevent crickets from climbing out of trenches. *A3*, inner wall prepared with road grader. *B3*, inner wall prepared by hand tools.

C. & D.—Pits in trench bottoms. *C*, incorrectly constructed, permitting crickets to travel in the trench without falling into the pit. *D*, correctly constructed.

E.—Fence constructed of lumber and tin or sheet metal, (6) face view, (7) end view.

F.—Illustrating method of lapping metal to cover joints between barriers.

Trenches are most effective in the early season before the insects are about two-thirds grown, and when the soil is moderately damp so that soil particles crumble when the crickets try to gain a foothold. After the exposed soil surface on the face of the trenches becomes dry and after the crickets attain considerable size they successfully climb out of trenches. Trenches constructed in loose, sandy soil or in heavy clay soil are relatively ineffectual since vertical sides cannot be maintained

Fig. 15.—Crickets "corralled" against a metal-wood fence where they were destroyed with sodium arsenite and with flame torches. Note the row of crickets on the board where they are prevented by the metal from climbing higher.

in sandy soil and clay soil is firm enough to allow crickets to crawl up the face of the trench at almost any stage of their development.

The most effectual trench is one dug by hand (*Fig.* 14*B*). It has perpendicular walls which are trimmed carefully until they are smooth and glazed. A very effectual trench could be constructed rapidly by mechanical trenching machines such as are used to dig trenches in which to lay sewer or drain pipes. Road grading machinery has been used extensively to construct trenches in Idaho but the trenches thus made have not been very effectual for sides are sloping and allow the crickets to crawl out. If trenches are made by the use of road graders the side away from the advancing band of crickets must be trimmed by hand and the bottom cleaned out carefully by hand if pits are to be even partially effective (*Fig.* 14*A*).

A properly constructed trench should be at least 2 feet deep and 1½ feet wide. The side of the trench toward the land which is to be protected should be vertical and the soil trimmed with a shovel or spade until it presents a smooth surface, free from roots or rocks. The most effective trench is one having both sides vertical (*Fig.* 14*B*). Dirt from the

trench should be thrown on the side away from the advancing crickets. If thrown on the side where the crickets are, it tends to change their direction of march, and also, soil particles are constantly loosened and pushed into the trench by the constantly moving insects (*Figs.* 14*A and* 14*B*). Trenches alone are of little value unless pits are dug in the bottoms of them to trap the crickets, which travel along the bottoms of the trenches after they have fallen into them. Pits should be at least 2

—From Colo. State Ent. Cir. 57.

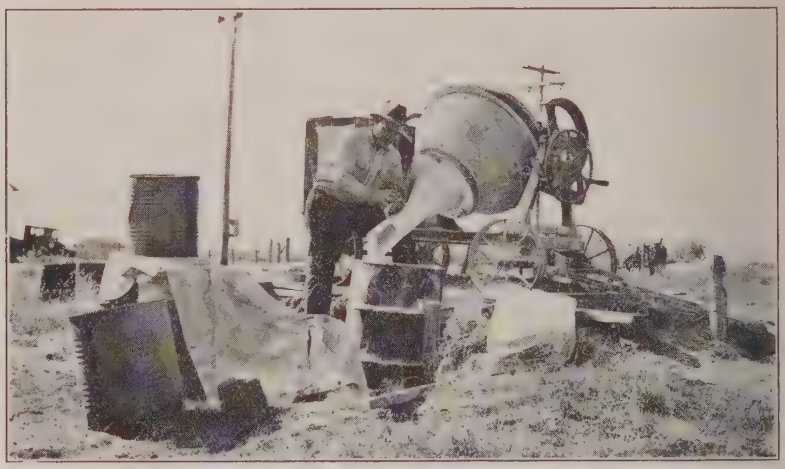
Fig. 16.—Closeup of hand dusting. Note how the dust is being blown into the clump of sage where the crickets usually gather during the heat of the day or at night and early morning. Observe also the canvas aprons worn by the operators.

feet deep, with smooth walls, and to be entirely effective, they should be as wide as the bottom of the trench, with no shoulders which would permit the insects to crawl past the pits without falling in (*Fig.* 14*D*). Very few crickets escape from properly constructed pits for they pull one another back in their efforts to climb out. Pits 18 inches wide and 2 feet deep soon become completely filled. Then new pits, adjacent to the old ones, should be dug and the old pits covered with earth.

After trenches are constructed, it is necessary to patrol them constantly to remove brush and weeds that lodge in them, to trim up the sides where crickets may be escaping, and to see that pits are functioning properly. It is difficult to secure sufficient labor to construct a trench rapidly, and very discouraging to workers to see migrating bands of crickets change their course, frustrating the plans made to entrap them, at such heavy labor cost. In general, trenching has not been very effective in Idaho and is too time-wasting to justify its use on an extensive scale.

Fences. Barrier fences have been used to some extent and occasionally they have proven effective in temporarily stopping migrating bands or in

changing their direction of march. From the standpoint of cash outlay they are very costly but from the standpoint of labor outlay they are much less expensive than trenches. Sheet metal fences are the most durable, most effective and the easiest to transport and store. These are made of galvanized iron cut in 8-inch or 10-inch strips. The barriers are erected vertically, lapped at the joints and held in place by iron stakes



—Photo by H. A. Ireland

Fig. 17.—Cement mixer adapted to use for mixing dust materials. Note tight cover to prevent dust from escaping and automobile inner tube over spout to guide the mixed dust into containers. This tube is lapped over the end of the metal tube and tied down while the mixer is in operation.

driven into the ground. The stakes are bent U-shape at the top so they clamp down over the upper edge of the metal strips, holding them in place. Sheet metal fences have not been used in Idaho because of their high cost, which is from $350 to $500 per mile. The barrier which has been used most in this state is made by nailing a 4-inch strip of bright metal on the surface of a board an inch in thickness and 8 inches or 10 inches wide. The metal is allowed to extend about 2 inches beyond one end of the board so that when the boards are placed end to end there is always a lap of metal to cover up rough edges on which crickets may gain a foothold (*Fig. 14E and 14F*). The boards are set on edge with the metal at the upper edge and facing toward the advancing crickets. The boards are held in place by wooden pegs driven in the ground on the side opposite the metal or by iron pegs as described for "Metal Barriers." The cost of wood-metal barriers is about $250 per mile.

Before fences are erected, the narrow strip on which they are to be placed needs to be cleared so there will be no brush to lessen their effectiveness and so that small irregularities on the soil surface may be smoothed out. After the fences are erected the bottoms are made cricket proof by piling soil against the bottoms on the side opposite the metal. Fences need to be patrolled daily to see that debris does not collect against

them, permitting crickets to crawl over them, and to see that no holes are opened beneath the fences.

When fences are available, they may be used effectively along a wide front to prevent crickets from reaching crop lands. It is necessary to erect a fence well in advance of a marching band and have it a mile or

—F. E. R. A. Photo

Fig. 18.—Barrel-type hand mixer. Easily and cheaply constructed, it thoroughly mixes together the dust materials. The opening in the head of the barrel should be covered with a tight-fitting, hinged lid.

more in length if it eventually is to be effective, for Mormon crickets may change their direction of march, a behavior which greatly lessens the possible usefulness of both trenches and fences. When trenches are constructed or fences are erected near the front of an advancing band, the noise and confusion incident to the work usually serves to change its direction of march and the crickets will avoid barriers which may have taken days to prepare. If barriers are erected well ahead of an advancing band, the band rarely reaches the barrier at the anticipated point. For these reasons fences or trenches rarely have been as helpful as it has been hoped they would be.

Where fences already are on hand they can be used to good advantage to protect a piece of land in crop by entirely enclosing it but the value of a given crop rarely if ever justifies purchasing fencing for that specific purpose.

Fences too often have been purchased inadvisedly and erected after the crickets were migrating to agricultural lands, with the result that there has not been time to place them in advance of the bands. Thus they often have served to hold the insects in the fields as well as to keep them out. Fences usually have been purchased by counties after the season is well advanced and crickets were destroying crops. The money necessary to purchase them could have been used much more advantageously

to kill the crickets by arsenical dusts early in the season before they had begun to migrate. The ineffectiveness of fences, generally, is attested to by the fact that much of the fencing purchased during the present outbreak has not been used.

Fig. 19.—A Mormon cricket control camp established in the heart of the infested area on the Fort Hall Indian Reservation, 1935.

Fences which have been purchased and prepared may be used for several years if they are cared for properly. As soon as need for them has passed for the season, they should carefully be collected and piled in a building where they can be kept dry and protected from warping and rusting. Crickets will crawl over metal which has become roughened by rusting.

Crickets may be trapped by digging pits at intervals, as already described under "Trenches", on occasions where they reach a fence. Pits should be as near to the face of the barrier as the type of soil in which they are dug will permit and on the metal-faced side. Fences are of the greatest benefit where used as an adjunct to dusting. The crickets then are held against the fences in very great numbers where they are economically killed by arsenical dusts (*Fig.* 15).

Protection of Gardens and Yards.

The most practical and economical means of protecting gardens and yards is to surround them entirely with a cricket fence early in the season. Annoyance and loss from the insects can be prevented completely by this precaution if the fence is patrolled occasionally to see that there are no openings and that weeds and grass do not grow against or over it, and that debris does not lodge against it, permittting crickets to crawl over the fence.

Control by Baiting.

Before it was known that sodium arsenite and calcium arsenite could be used for cricket control, poisoned bran baits similar to those used for grasshopper control were used for Mormon cricket control. They were far from satisfactory, however, because the crickets did not feed upon them with any degree of consistency. The crickets migrate from one place to another, as already mentioned, and under favorable weather conditions they may move great distances without feeding. Thus if bait is spread

where they are present at the time of baiting they may migrate to remote areas without feeding on the bait. If the bait is scattered for them where they may seem to be going they may change the direction of migration and not approach the bait at all. To be effective this type of bait must be moist and if not eaten by the crickets before it has dried it becomes less and less attractive from hour to hour. Within a day it may become entirely unattractive to the insects and the bait and labor of scattering it will have been wasted. Experimental work is now being conducted to determine the effectiveness of other types of baits. Nothing yet is known to be as effective as dusting with poisoned dusts as described in this Bulletin.

Control by Dusting.

Various dusting and spraying materials have been used experimentally in the control of Mormon crickets. It has been found that of the poisons tried, a dust made of sodium arsenite or calcium arsenite mixed with hydrated lime produced the best results. Care must be taken that the operator of the mixing machine does not inhale the dust or that too much of the material does not come in contact with his body. For this reason it is advisable to do the mixing out of doors where breezes will carry away the air-suspended poison particles.

Hydrated lime may be obtained from local building material dealers. The arsenicals may be obtained from The Chipman Chemical Co., Boundbrook, N. J.; The Grasselli Chemical Co., Cleveland, Ohio; the Miller Products Co., Portland, Ore.; and the Spinner Co., Yakima, Washington.

The dust is applied directly to the bodies of the insects by means of hand-operated dust guns of the crank type (*Fig.* 16). The materials are applied rather sparingly and so that they reach the bodies of the insects without an excess of the dust getting on the ground. Care must be taken in filling the dust guns that the poisoned materials are not spilled on the vegetation or on the ground. Excess materials poison animals or burn foliage. The arsenites recommended have a salty taste and therefore are atractive to domestic and game animals which do not regularly obtain salt. Materials spread thinly will not endanger the lives of animals or plants.

Sodium arsenite is mixed with wind-blown hydrated lime at the rate of one part sodium arsenite to four parts hydrated lime. If calcium arsenite is used it is mixed in the proportions of one to three. The materials must be thoroughly mixed and the mixing may be done in a concrete mixer (*Fig.* 17) revolving at a very slow speed or by placing the materials in a tightly covered hand-mixer (*Fig.* 18) which is revolved slowly until the mixing is completed (about 20 minutes). A practical mixer may be made by cutting a hole in the head of a 50-gallon oil drum, hinging over it a tight-fitting lid, and mounting it as shown in Figure 18. Neither of these mixers should be more than one third full of dust. The revolving and sliding actions produce a very uniform mixture.

The ideal time for dusting is just after the crickets hatch and not, as is the usual practice, after they have begun to migrate. In the early season they are much more concentrated and therefore easier to dust. They also are smaller so require less dust to kill them, and less labor

is involved in dusting them. If killed early in the season, damage is prevented and there is no opportunity for them to lay eggs which will produce more crickets the followng year.

Crickets are killed by coming in direct contact with the dust. They congregate in bunches in the late evening and early in the morning or during unusually hot or cold periods. If possible, control efforts should be concentrated on them while they are bunched. An effort should be directed towards dusting the vanguard of bands migrating into agricultural fields, the dusting work progressing from the agricultural land towards the migrating band. This procedure serves to kill many of the crickets in the vanguard and repulse their advance. It should be borne in mind that the crickets are easily excited and scattered and that quiet, systematized work of a few individuals is far more effective than haphazard, noisy efforts of large numbers of men. (*Fig.* 20). It often is possible for an individual farmer to protect his crops from crickets if he has at hand a dust gun and mixed poison so he can dust small migrating bands where they are entering his place.

Cricket control is economical if care is exercised not to waste material. Dust guns should be turned at a slow rate and the dust applied only where there are numbers of crickets bunched. Five pounds of mixed dust is sufficient to cover very thoroughly an infested acre. This amount of mixed dust will treat much more than an acre if used only where crickets are congregated.

Arsenite dusts make their way through ordinary clothing and cause serious sores on perspiring areas of the body. It is advisable to wear heavy canvas aprons to aid in avoiding this difficulty (*Fig* 16). Operators of dust guns should use every precaution to prevent breathing or working in poisoned dust floating in the air. Experience has shown that masks intended to prevent breathing the dust have collected arsenicals and caused sores on perspiring skin areas. Operators soon learn to do efficient work and still avoid subjecting themselves to excessive quantities of dust by working in proper relation to the wind or prevailing air currents. They should wash themselves thoroughly and apply a skin lotion each time after using the dust and should not wear clothing which has become impregnated with arsenicals. *In case of illness from internal poisoning, give an emetic of mustard and call a physician.*

When sodium or calcium arsenite dust comes in contact with the body of the Mormon cricket it causes the insect to clean the material from its antennae and legs and in so doing the poison is taken into the body, where it enters the digestive tract and causes death of the individual. Insects which have been poisoned first show the effects by becoming sluggish. The poison causes violent reaction of the digestive tract. The fecal deposits are green and liquid. Before death the insects attempt to seclude themselves under some object where the temperature is lower, and there they usually die. Because of this they very often are difficult to find after they have been killed.

Cooperation Necessary for Control

The natural habitat of the Mormon cricket is in the rough uncultivated areas from which they migrate to agricultural lands when food becomes

Fig. 20—A group of men armed with hand dusters advancing on a band of crickets.

less plentiful or when the crickets occur in large bands. They migrate constantly and because of this habit they are not located permanently in any one area. One person trying to fight them alone may succeed in driving them from his land but they move on to neighboring areas. They are found on forest service land, on other public domain land, such as grazing areas, on abandoned land and on private land. For these reasons it is desirable that all of the people in an infested area cooperate in their control. Since these insects must be controlled in remote areas in order that they may be prevented from reaching agricultural land, it is necessary that all who might be in the path of their migrations assist in their control.

Since their habits of migration vary so greatly, it is impossible to determine the direction of migrations and therefore to determine who might be affected by the insects. When they occur in large numbers control necessarily is a cooperative problem.

When the insects occur in outbreak numbers, the magnitude of the situation demands that all control operations have exacting supervision. This expedient often is neglected in large control campaigns where many persons are involved. Proper supervision by men trained in the control of the insect, so that grave errors and waste of funds and time may be averted, is necessary. Technical supervision should come from the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture; the State Agricultural Experiment Station or the University Agricultural Extension Divison. The personnel of the supervisory staff should be well trained in insect control in general and have had experience in fighting Mormon crickets. Each county needs some one who understands cricket control in charge of the operations in that county and under the direct supervision of those trained in the control of this insect. Each community also should employ a man to properly lead and direct the control operations of each crew of men working on the projects.

The greatest item of expense aside from materials for the actual poisoning of the insects is the labor. Labor crews should be composed of the same personnel throughout the season. Once trained, they can be expected to do increasingly more efficient work and thus avoid the dangers of poisoning due to careless, untrained labor. Men who work carefully and quietly are a necessity in successful cricket control. (*Fig.* 20).

Adequate facilities for transportation of both the men and materials must be made available, where the crickets are located at some distances from the centers of population. Provision also should be made for locating the bands of crickets for each day's dusting so that the time of the control crews will not be wasted. A truck is necessary for the transportation of each crew of not more than 10 or 12 men and their equipment.

Where the crickets are located in areas remote from the homes of the laborers it is desirable that camps be established. This has been done successfully in the Fort Hall area (*Fig.* 19). It should be done in all areas remote from the centers of population so the same crews may be available each day, thus reducing the cost of transportation to and from the infested areas and using all the time of the crew for actual control

work. Camps should provide suitable living quarters for the crews, efficient field equipment for preparation of food, and facilities for hot and cold water to be used in the bath after each day's work.

Financing for Mormon Cricket Control

The greatest handicap to successful cricket control is the lack of funds to meet its cost. Farmers on isolated ranches might well afford to purchase a supply of sodium arsenite, hydrated lime and hand dusters to use in preventing damage to their crops and to turn back invading bands. In many instances, individual farmers have saved their crops by the investment of a few dollars in protection.

Counties faced with a cricket outbreak should provide funds for control in their county in proportion to the severity of the infestation. Several counties have done this but thus far, such funds have not been used very effectively, because they were not provided until late in the season when crickets had migrated to crop lands, when it was too late for successful control. Counties could, with foresight, appropriate reasonable sums which would assure effective control of the insects in the spring before they attack crops.

No state funds have been available for use in the present cricket outbreak. Officers and citizens of infested counties should reasonably demand and expect to obtain a state appropriation to be used in supplementing county appropriations for Mormon cricket control. A special appropriation for this purpose is necessary, if state funds are to be obtained, for no funds are available out of any general state appropriations at this time.

A small amount of federal money has been expended for cricket control to date in the present outbreak. This was provided by the United States Department of the Interior, and was used on the Fort Hall Indian Reservation. Allotments were made by the Idaho Emergency Relief Administration for materials in 1934 and for labor in 1935. A congressional appropriation is needed for cricket control work in the present outbreak in all of the eight western states that are affected, the work to be administered by the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in cooperation with the entomological organizations of each of these states.

A state Works Progress Administration project has been approved for Mormon cricket control in Idaho in 1936, which will assure control work in all the main infested areas near agricultural lands, in the 24 infested counties, if funds are made available in time.

Summarizing the subject of financing Mormon cricket control, adequate and successful control can be accomplished only by each political division bearing its proportion of the total cost. Individuals, communities, counties, the State and the federal government should all share in the cost and eventually must do so to reduce the constantly increasing hordes of Mormon crickets unless unknown "natural conditions" become operative as they appear to have done in previous outbreaks.

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